US011891866B2

(12) **United States Patent**
Passmore et al.

(10) **Patent No.: US 11,891,866 B2**
(45) **Date of Patent: Feb. 6, 2024**

(54) **DAMPENING THE ACTUATION SPEED OF A DOWNHOLE TOOL**

(71) Applicant: **HALLIBURTON ENERGY SERVICES, INC.**, Houston, TX (US)

(72) Inventors: **Kevin Robin Passmore**, Dallas, TX (US); **Bruce Edward Scott**, McKinney, TX (US); **James D. Vick, Jr.**, Mineral Wells, TX (US)

(73) Assignee: **Halliburton Energy Services, Inc.**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/374,088**

(22) Filed: **Jul. 13, 2021**

(65) **Prior Publication Data**

US 2023/0014780 A1 Jan. 19, 2023

(51) **Int. Cl.**
E21B 23/00 (2006.01)
E21B 34/06 (2006.01)
E21B 41/00 (2006.01)

(52) **U.S. Cl.**
CPC ***E21B 23/00*** (2013.01); ***E21B 34/06*** (2013.01); ***E21B 41/00*** (2013.01)

(58) **Field of Classification Search**
CPC E21B 23/00; E21B 34/06; E21B 41/00
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,638,895 A 1/1987 Taylor et al.
5,050,681 A * 9/1991 Skinner E21B 41/00 166/66.4
7,487,829 B2 2/2009 McDonald et al.
2012/0205122 A1* 8/2012 Peter E21B 34/085 166/321
2012/0228029 A1 9/2012 Reimers
(Continued)

FOREIGN PATENT DOCUMENTS

CN 108019171 A 5/2018

OTHER PUBLICATIONS

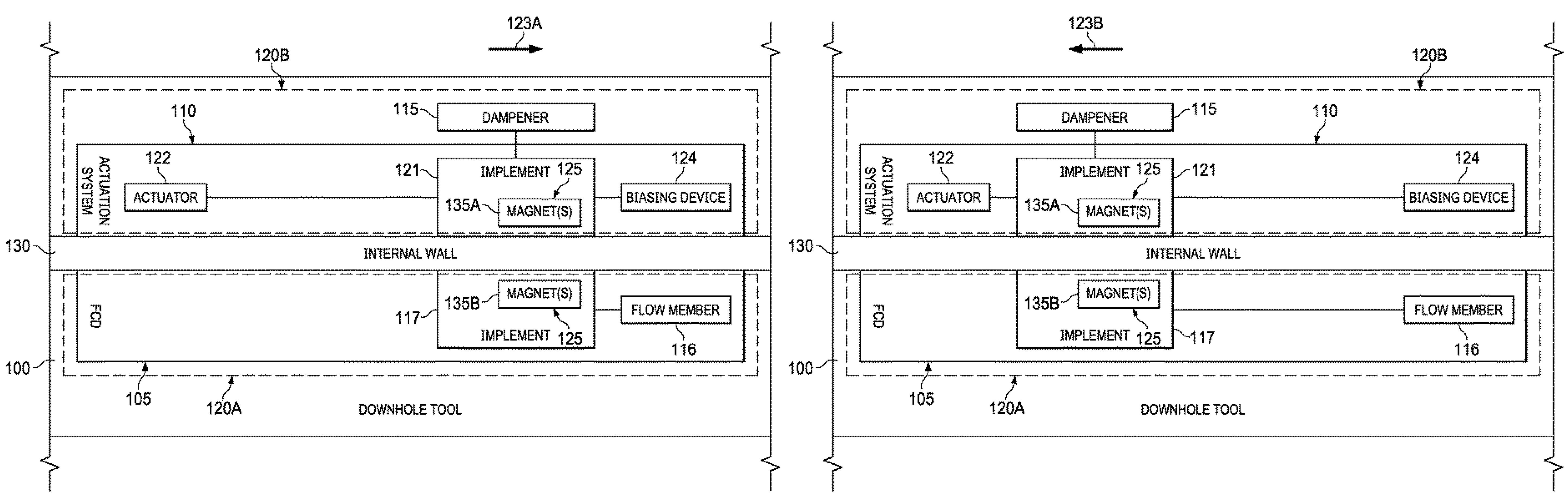
"Labyrinth seal," Web page Wikipedia, <www.en.wikipedia.com>, 2 pages, retrieved from the Internet <http. https://en.wikipedia.org/wiki/Labyrinth_seal>, on May 14, 2021.
(Continued)

Primary Examiner — Brad Harcourt
(74) *Attorney, Agent, or Firm* — Scott Richardson; Parker Justiss, P.C.

(57) **ABSTRACT**

An actuator of a downhole tool used in oil and gas exploration and production operations is operable to actuate a first implement in a first direction. A biasing device of the downhole tool is operable to actuate the first implement in a second direction, opposite the first direction. A dampener of the downhole tool is operable to slow an actuation speed of the first implement in the first direction, the second direction, or both. Actuating the first implement in the first direction also actuates a second implement of a flow control device ("FCD") of the downhole tool, to which the first implement is connected, in the first direction, placing the FCD in a first (e.g., open) configuration. Actuating the first implement in the second direction also actuates the second implement of the FCD in the second direction, placing the FCD in a second (e.g., closed) configuration.

15 Claims, 7 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2013/0327537	A1*	12/2013	Anyan	E21B 34/102 166/373
2015/0211333	A1	7/2015	Vick, Jr. et al.	
2016/0258252	A1*	9/2016	Fripp	E21B 34/10
2018/0238131	A1*	8/2018	Mackenzie	E21B 23/006
2018/0347313	A1*	12/2018	Joseph	E21B 34/066
2019/0242211	A1	8/2019	Vasques	

OTHER PUBLICATIONS

“Labyrinth seal review,” Web page <www.engineersedge.com>, 2 pages, retrieved from the Internet <https://www.engineersedge.com/fluid_flow/labyrinth-seal-concept.htm#:~:text=Labyrinth%20Seal%20Review%20%2D%20Engineers%20Edge&text=A%20labyrinth%20seal%20is%20a,the%20oil%20lubricating%20the%20bearingon>, on May 14, 2021.

International Search Report and The Written Opinion of the International Search Authority, or the Declaration, Nov. 2, 2021, PCT/US2021/041412, 10 pages, ISA/KR.

* cited by examiner

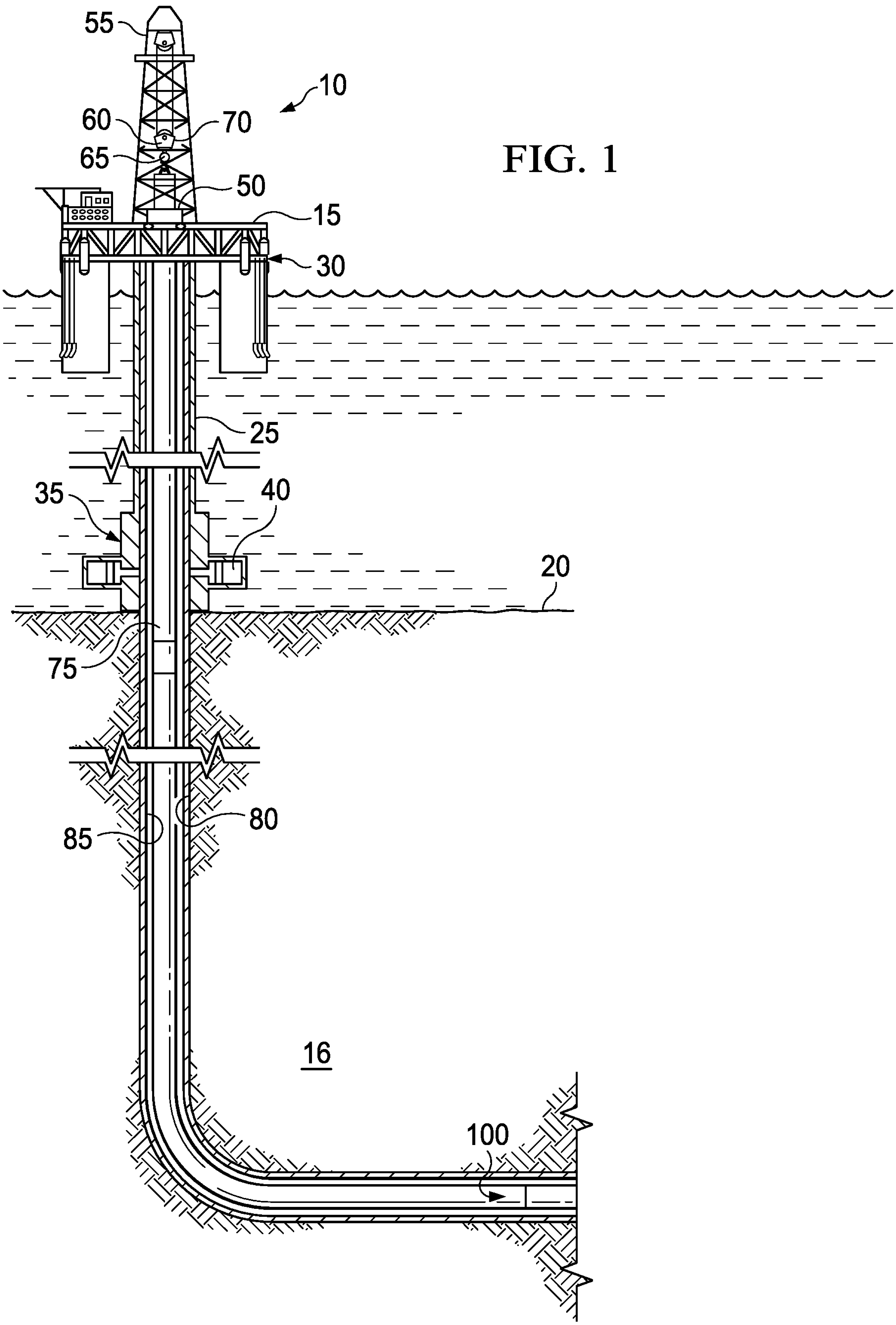


FIG. 1

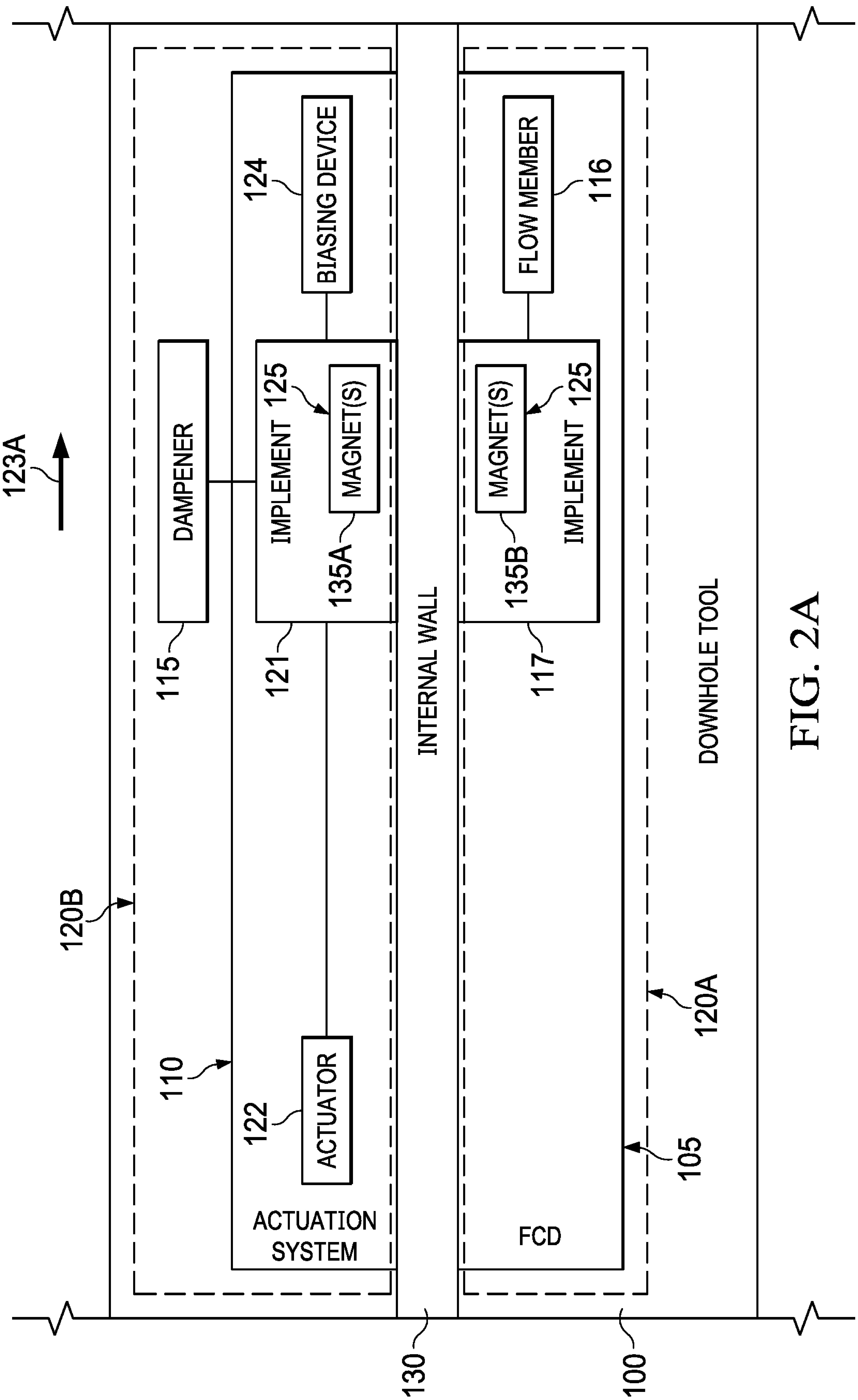

123A
120B
DAMPENER
115
IMPLEMENT
125
MAGNET(S)
135A
121
BIASING DEVICE
124
110
ACTUATOR
122
ACTUATION SYSTEM
INTERNAL WALL
FLOW MEMBER
116
MAGNET(S)
125
135B
IMPLEMENT
117
FCD
DOWNHOLE TOOL
120A
105
130
100

FIG. 2A

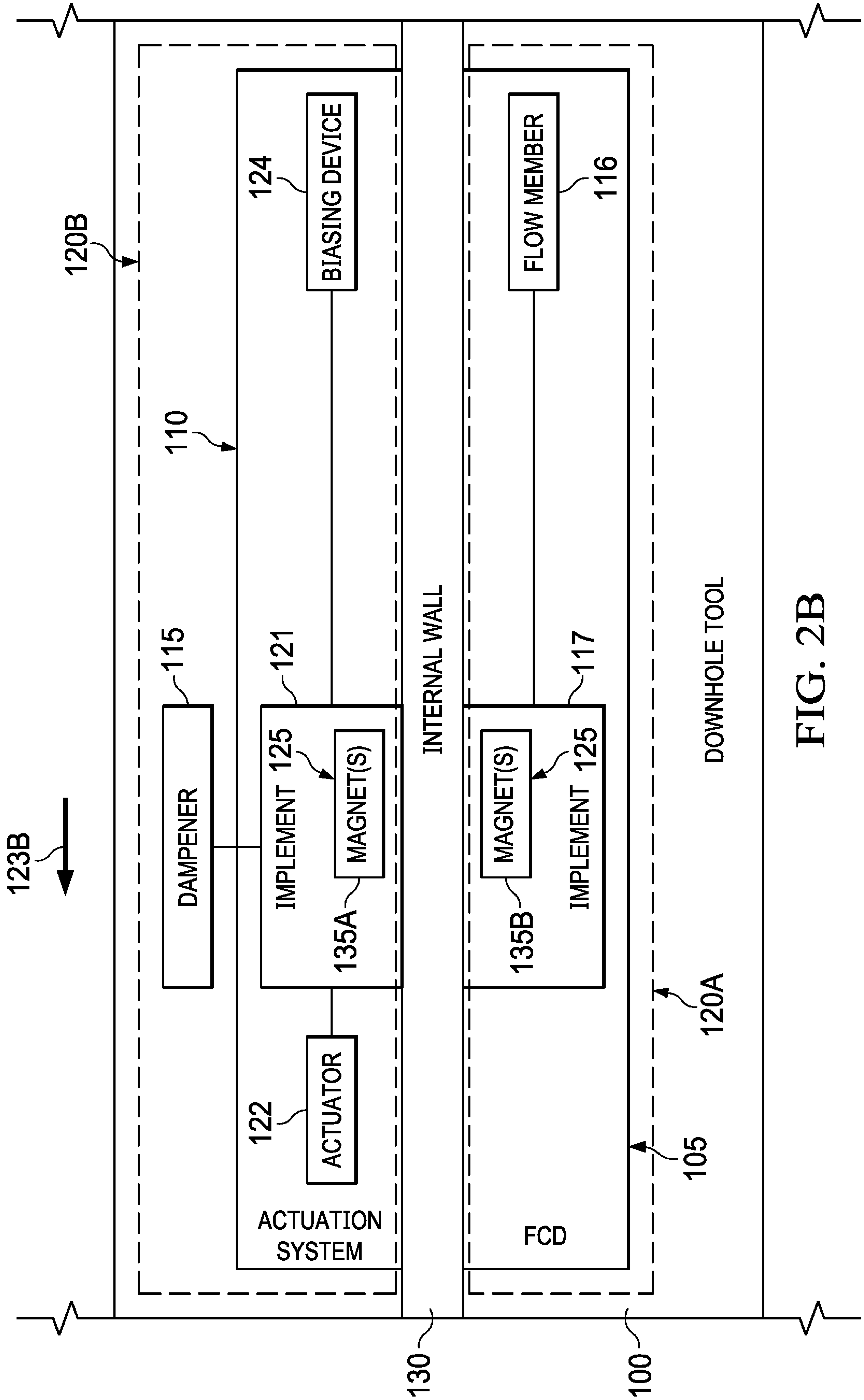

120B
110
124
BIASING DEVICE
FLOW MEMBER
116
123B
115
DAMPENER
121
IMPLEMENT
125
MAGNET(S)
135A
INTERNAL WALL
117
MAGNET(S)
125
IMPLEMENT
135B
DOWNHOLE TOOL
120A
122
ACTUATOR
ACTUATION SYSTEM
FCD
105
130
100

FIG. 2B

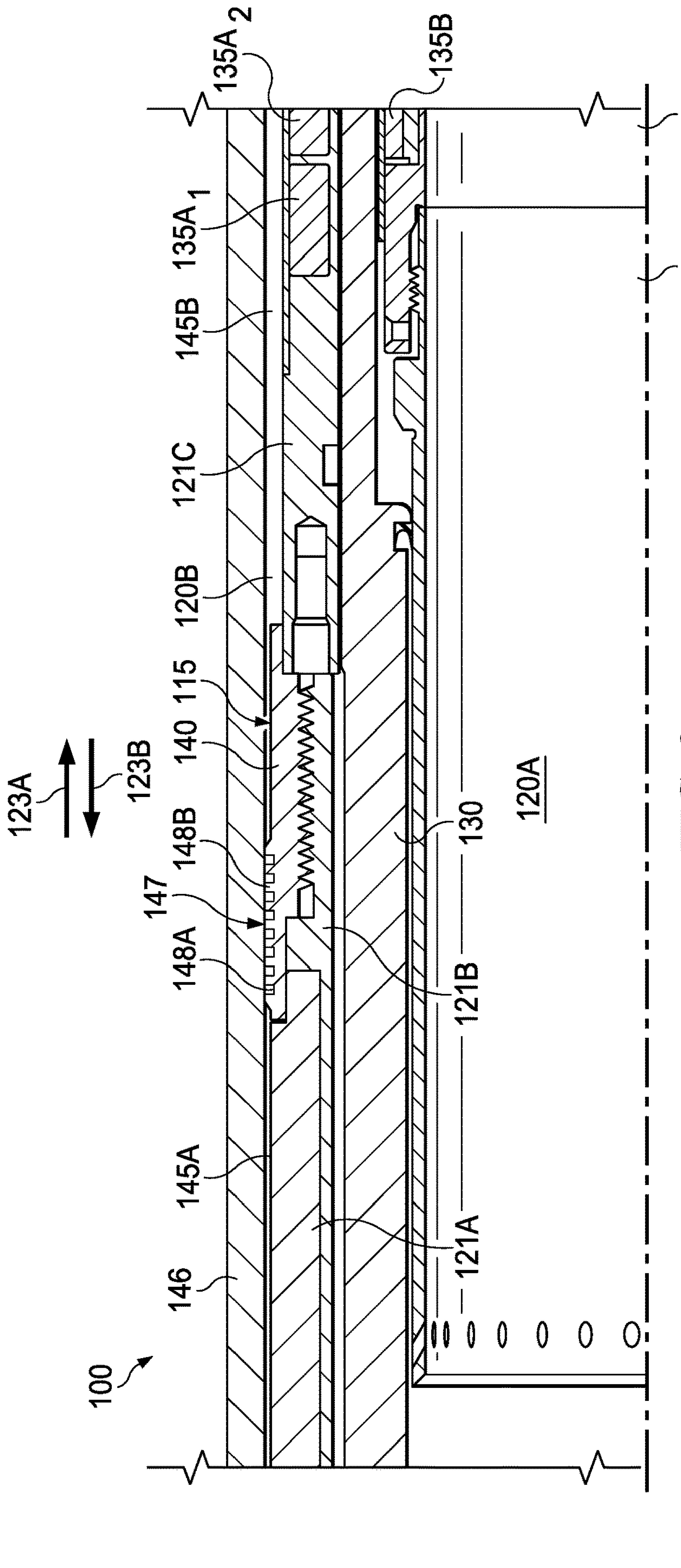

135A2
135B
117B
135A1
117A
145B
121C
120B
115
140
123A
123B
148B
147
148A
130
120A
121B
145A
121A
146
100

FIG. 3

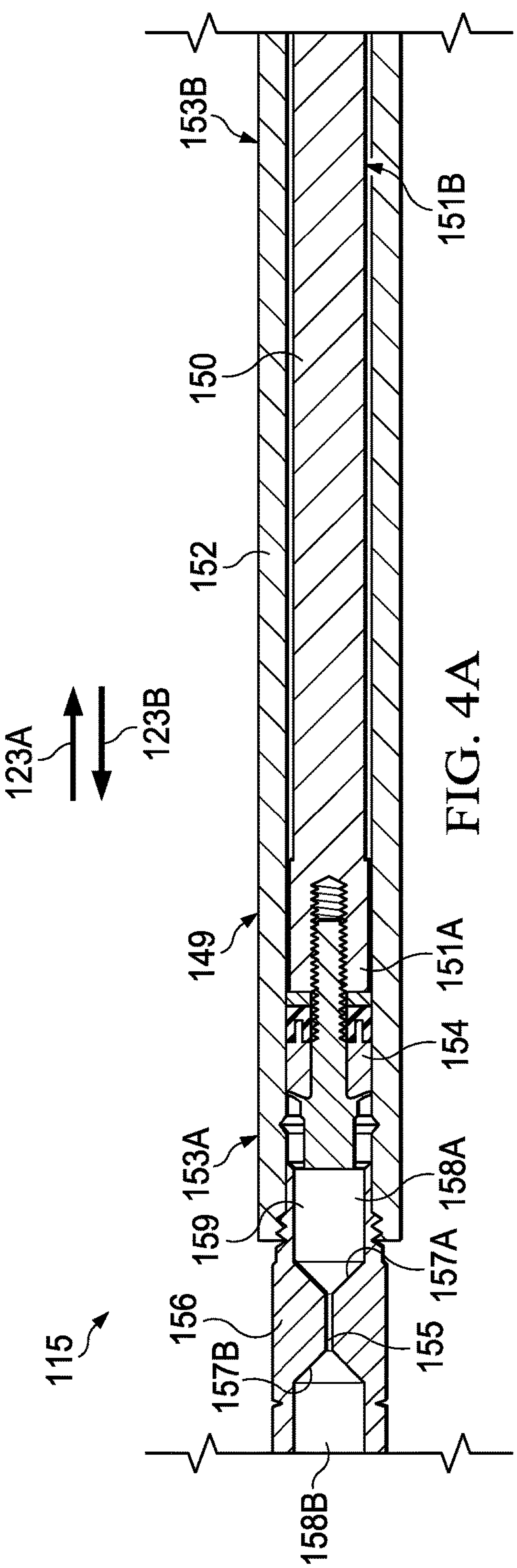

153B
151B
150
152
123A
123B
149
151A
154
153A
159
158A
157A
156
155
157B
158B
115

FIG. 4A

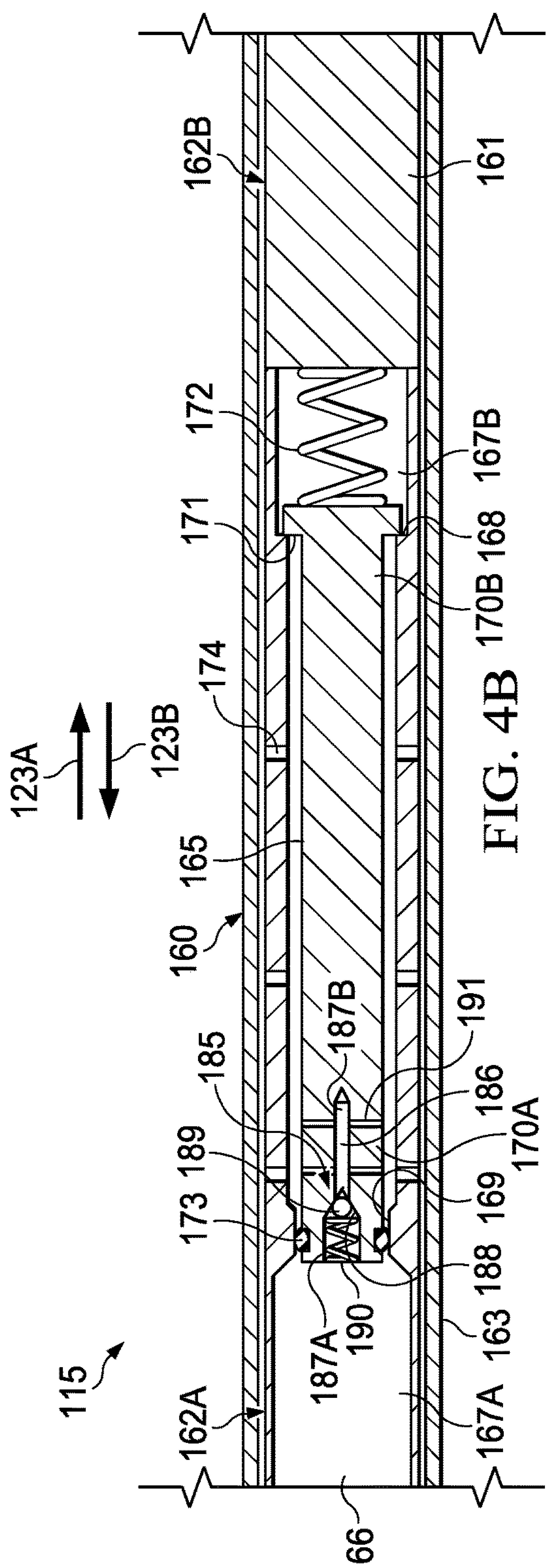

162B
161
172
167B
171
168
170B
174
123A
123B
165
160
187B
191
185
186
170A
189
169
173
188
190
187A
163
162A
167A
166
115

FIG. 4B

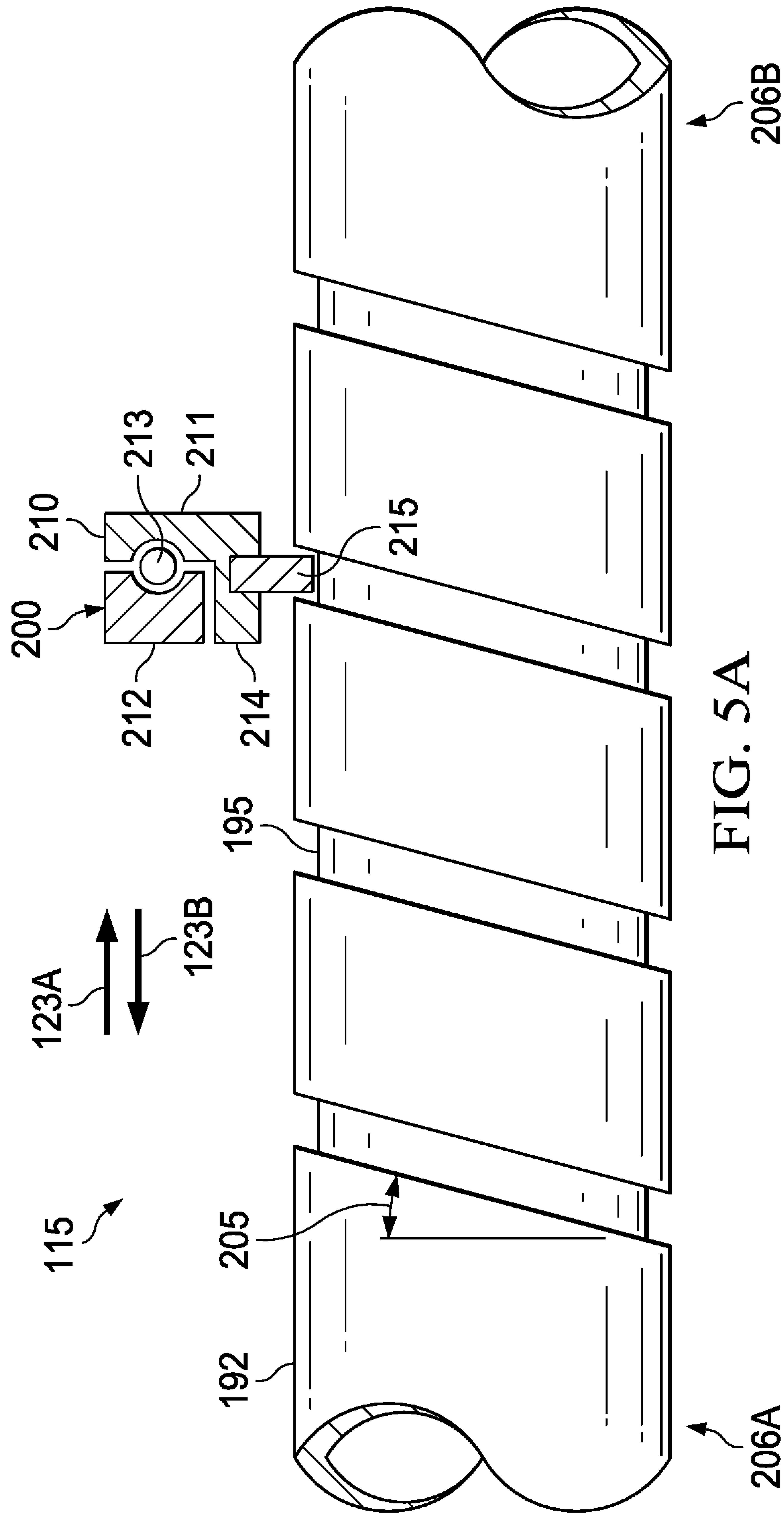


FIG. 5A

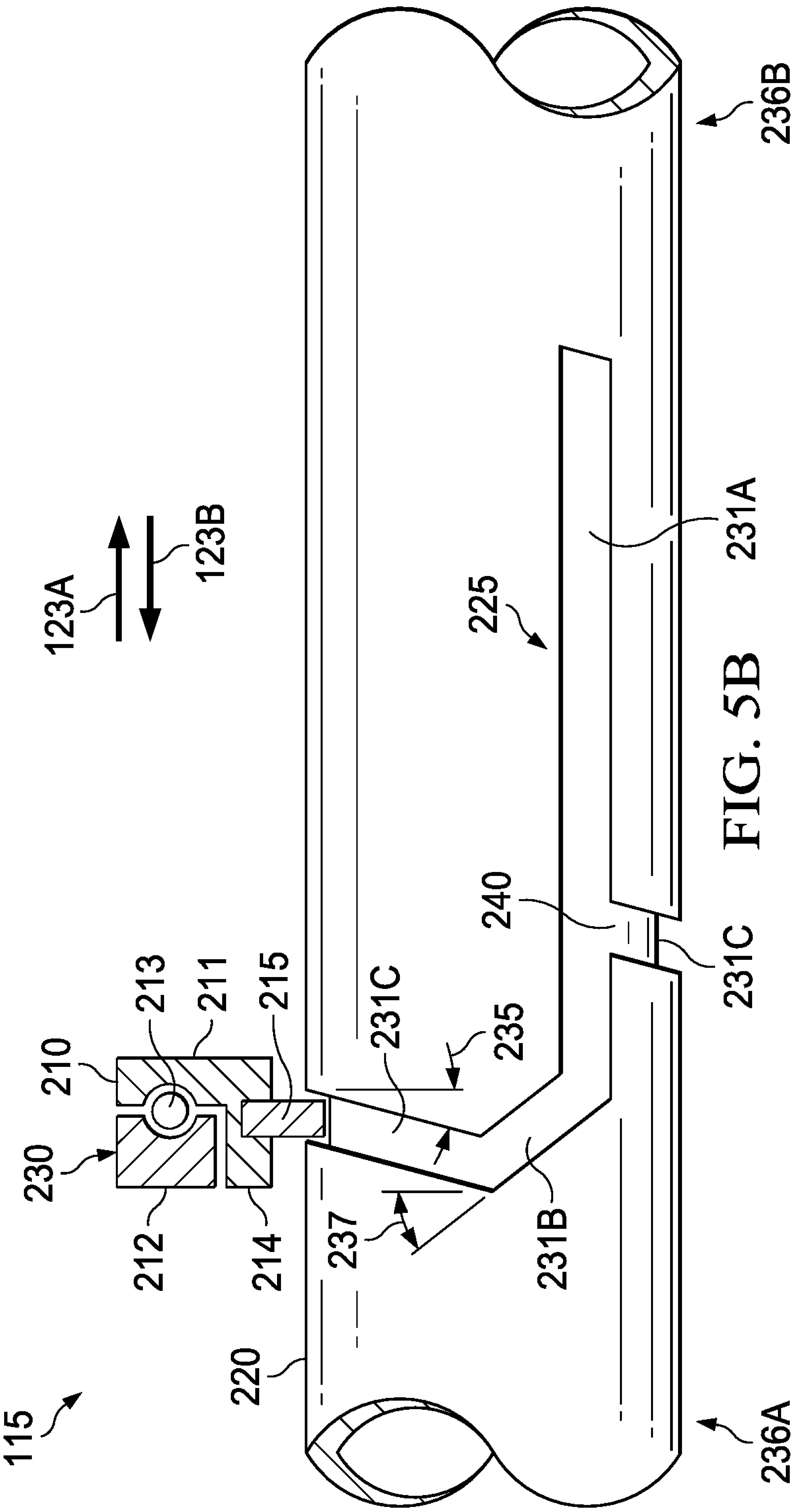

123A
123B
225
231A
236B
240
231C
231C
235
215
213
211
210
230
212
214
237
231B
220
115
236A

FIG. 5B

DAMPENING THE ACTUATION SPEED OF A DOWNHOLE TOOL

TECHNICAL FIELD

The present disclosure relates generally to downhole tools for use in oil and gas exploration and production operations and, more particularly, to dampening the actuation speed of a downhole tool.

BACKGROUND

In some instances, it is desirable to dampen the actuation speed of a downhole tool. For example, when a downhole tool uses a powerful actuation mechanism, such as a spring, dampening the actuation speed may be necessary to ensure proper actuation of the downhole tool without damaging the downhole tool or other systems/devices associated with the downhole tool.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic illustration of an offshore oil and gas platform connected to a downhole tool, according to one or more embodiments.

FIG. **2**A is a diagrammatic illustration of the downhole tool of FIG. **1** in a first operational state or configuration, the downhole tool including an actuation system, a flow control device, and a dampener, according to one or more embodiments.

FIG. **2**B is a diagrammatic illustration of the downhole tool of FIG. **1** in a second operational state or configuration, according to one or more embodiments.

FIG. **3** is a cross-sectional view of the downhole tool of FIGS. **1**, **2**A, and **2**B according to one or more embodiments in which the dampener is or includes a labyrinth seal.

FIG. **4**A is a cross-sectional view of the dampener of FIGS. **2**A and **2**B according to one or more embodiments in which the dampener is or includes a guide rod assembly including a guide rod and an orifice.

FIG. **4**B is a cross-sectional view of the dampener of FIGS. **2**A and **2**B according to one or more embodiments in which the dampener is or includes a guide rod assembly including a guide rod with an integral pressure relief member and a secondary miniature relief valve.

FIG. **5**A is a partial cross-sectional view of the dampener of FIGS. **2**A and **2**B according to one or more embodiments in which the dampener is or includes a sleeve having a slot such as, for example, a helical slot formed therein, and a guide adapted to engage the helical slot.

FIG. **5**B is a partial cross-sectional view of the dampener of FIGS. **2**A and **2**B according to one or more embodiments in which the dampener is or includes a sleeve having a slot such as, for example, a J-slot formed therein, and a guide adapted to engage the J-slot.

DETAILED DESCRIPTION

The disclosure may repeat reference numerals and/or letters in the various examples or figures. This repetition is for simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. Further, spatially relative terms, such as beneath, below, lower, above, upper, uphole, downhole, upstream, downstream, and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated,

the upward direction being toward the top of the corresponding figure and the downward direction being toward the bottom of the corresponding figure, the uphole direction being toward the surface of the wellbore, the downhole direction being toward the toe of the wellbore. Unless otherwise stated, the spatially relative terms are intended to encompass different orientations of the apparatus in use or operation in addition to the orientation depicted in the figures. For example, if an apparatus in the drawings is turned over, elements described as being "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the exemplary term "below" can encompass both an orientation of above and below. The apparatus may be otherwise oriented (i.e., rotated 90 degrees) and the spatially relative descriptors used herein may likewise be interpreted accordingly.

Referring to FIG. **1**, in an embodiment, an offshore oil and gas rig is schematically illustrated and generally referred to by the reference numeral **10**. In an embodiment, the offshore oil and gas rig **10** includes a semi-submersible platform **15** that is positioned over a submerged oil and gas formation **16** located below a sea floor **20**. A subsea conduit **25** extends from a deck **30** of the platform **15** to a subsea wellhead installation **35**. One or more pressure control devices **40**, such as, for example, blowout preventers (BOPs), and/or other equipment associated with drilling or producing a wellbore may be provided at the subsea wellhead installation **35** or elsewhere in the system. The platform **15** may also include a hoisting apparatus **50**, a derrick **55**, a travel block **60**, a hook **65**, and a swivel **70**, which components are together operable for raising and lowering a conveyance string **75**. The conveyance string **75** may be, include, or be part of, for example, a casing, a drill string, a completion string, a work string, a pipe joint, coiled tubing, production tubing, other types of pipe or tubing strings, and/or other types of conveyance strings, such as wireline, slickline, and/or the like. The platform **15** may also include a kelly, a rotary table, a top drive unit, and/or other equipment associated with the rotation and/or translation of the conveyance string **75**. A wellbore **80** extends from the subsea wellhead installation **35** and through the various earth strata, including the submerged oil and gas formation **16**. In some embodiments, as in FIG. **1**, at least a portion of the wellbore **80** includes a casing **85** cemented therein. A downhole tool **100** extends within the wellbore **80** and is connected to the conveyance string **75**.

Referring to FIGS. **2**A and **2**B, in an embodiment, the downhole tool **100** includes a flow control device ("FCD") **105**, an actuation system **110**, and a dampener **115**. The FCD **105** includes a flow member **116** and an implement **117** via which the actuation system **110** is adapted to move the flow member **116** between first (e.g., open or partially-open) and second (e.g., closed) configurations, as will be described in further detail below. The FCD **105** is disposed within an internal space **120***a* of the downhole tool **100**; for example, the FCD **105** may be disposed within a central flow passage of the downhole tool **100**. In one or more embodiments, the FCD **105** is or includes a subsurface safety valve ("SSSV"). In addition, or instead, the FCD **105** may be or include flow control device such as, for example, a valve (e.g., a flapper valve, a gate valve, a ball valve, a plug valve, the like, another type of valve, or a combination thereof), another (at least partially) translationally actuable flow control device (e.g., a plug, a packer, etc.), the like, or a combination thereof.

The actuation system **110** is disposed within an internal space **120***b* of the downhole tool **100**. In one or more embodiments, the internal space **120***b* of the downhole tool **100** in which the actuation system **110** is disposed is external to the internal space **120***a* in which the FCD **105** is disposed; for example, the internal space **120***b* may be an annular space external to the central flow passage in which the FCD **105** is disposed. Alternatively, the internal space **120***b* of the downhole tool **100** in which the actuation system **110** is disposed may be, include, or overlap with the internal space **120***a* of the downhole tool **100** in which the FCD **105** is disposed. The actuation system **110** includes an implement **121**, an actuator **122** operable to move the implement **121** in a direction **123***a*, and a biasing device **124** (e.g., a spring, a hydraulic or pneumatic device, the like, etc.) operable to move the implement **121** in a direction **123***b*, opposite the direction **123***a*. In one or more embodiments, the actuator **122** is or includes an electric motor. In addition, or instead, the actuator **122** may be or include another source of mechanical energy (e.g., hydraulic, pneumatic, the like, etc.) capable of moving the implement **121** in the direction **123***a*.

A coupler **125** connects the implement **121** of the actuation system **110** to the implement **117** of the FCD **105**. In one or more embodiments, the coupler **125** is or includes a magnetic coupler connecting the implement **121** of the actuation system **110** to the implement **117** of the FCD **105** through an internal wall **130** (e.g., a tubular wall, such as a cylindrical wall) of the downhole tool **100**, which internal wall **130** separates the internal space **120***a* in which the FCD **105** is disposed from the internal space **120***b* in which the actuation system **110** is disposed; in such embodiment(s), the coupler **125** includes magnetic devices **135***a* and **135***b* connected to or otherwise associated with or incorporated into the implement **121** of the actuation system **110** and the implement **117** of the FCD **105**, respectively, which magnetic devices **135***a* and **135***b* are magnetically coupled to one another through the internal wall **130** of the downhole tool **100**. Alternatively, the coupler **125** may be omitted and the implement **121** may be integrally formed with, or otherwise connected to the implement **117**. The dampener **115** is connected to the implement **121** of the actuation system **110** to slow the actuation speed of the downhole tool **100** in the direction **123***a*, the direction **123***b*, or both. In one or more embodiments, the dampener **115** is disposed within the internal space **120***b* of the downhole tool **100**, together with the actuation system **110**. Alternatively, the dampener **115** may be connected to the implement **117** of the FCD **105** to slow the actuation speed of the downhole tool **100** in the direction **123***a*, the direction **123***b*, or both. In one or more embodiments, the dampener **115** is disposed within the internal space **120***a* of the downhole tool **100**, together with the FCD **105**.

In operation, the actuation system **110** is movable in the direction **123***a* to actuate the FCD **105**; for example, the implement **121** of the actuation system **110** may be movable using the actuator **122**, in the direction **123***a*, to move the implement **117** of the FCD **105** in the direction **123***a* (via the coupler **125**), thereby opening (or closing) the flow member **116** to allow fluid flow through the internal space **120***a*. The biasing device **124** accumulates potential energy during the movement of the implement **121** in the direction **123***a*. In one or more embodiments, the dampener **115** slows the actuation speed of the implement **121** in the direction **123***a*, as will be described in further detail below. Similarly, the actuation system **110** is movable in the direction **123***b* to actuate the FCD **105**; for example, the implement **121** of the actuation system **110** may be movable using the biasing device **124**, in the direction **123***b* (via the coupler **125**), to move the implement **117** of the FCD **105** in the direction **123***b*, thereby closing (or opening) the flow member **116** to block fluid flow through the internal space. The potential energy accumulated in the biasing device **124** during the movement of the implement **121** in the direction **123***a* is released as kinetic energy to move the implement **121** in the direction **123***b*. In one or more embodiments, the dampener **115** slows the actuation speed of the implement **121** in the direction **123***b*, as will be described in further detail below.

In one or more embodiments, the dampener **115** dampens the actuation speed of the downhole tool **100** in the direction **123***a*, the direction **123***b*, or both, thereby ensuring proper actuation of the downhole tool **100** without damaging the downhole tool **100** or other systems/devices associated with the downhole tool **100**.

Referring to FIG. **3**, in an embodiment, the dampener **115** is or includes a labyrinth seal **140** that slows the actuation speed of the downhole tool **100**, which labyrinth seal **140** functions to restrict the flow of a dampening fluid **145**, as will be described in further detail below. In one or more embodiments, the labyrinth seal **140** slows the actuation speed of the downhole tool **100** in the direction **123***b* without impacting the actuation speed of the downhole tool **100** in the direction **123***a*. In addition, or instead, the labyrinth seal **140** may be operable to slow the actuation speed of the downhole tool **100** in the direction **123***a* without impacting the actuation speed of the downhole tool **100** in the direction **123***b*. As shown in FIG. **3**, the labyrinth seal **140** is disposed within the internal space **120***b* of the downhole tool **100**, which internal space **120***b* is or includes an annular space between the internal wall **130** of the downhole tool **10** and an external wall **146**.

The implement **121** of the actuation system **110** is also disposed within the internal space **120***b* of the downhole tool **100** and includes interconnected implement segments **121***a-c*. The actuator **122** is connected to the implement segments **121***a* and/or **121***b* to move the implement **121** in the direction **123***a*. Likewise, the biasing device **124** is connected to the implement segment **121***c* to move the implement **121** in the direction **123***b*. The magnetic device **135***a*, including magnets **135***a***1**-N, is embedded in or otherwise connected to the implement segment **121***c*. The implement **117** of the FCD **105** is disposed within the internal space **120***a* of the downhole tool **100**, which internal space **120***a* is or includes a central flow passage inside the internal wall **120** of the downhole tool **100**. The implement **117** includes interconnected implement segments **117***a* and **117***b*. The flow member **116** is connected to the implement segment **117***b* so that, when the implement **117** moves in the direction **123***a* the flow member **116** opens (or closes) the central flow passage, and, when the implement **117** moves in the direction **123***b*, the flow member **116** closes (or opens) the central flow passage. Additionally, the magnetic device **135***b*, including magnets **135***b***1**-N, is embedded in or otherwise connected to the implement segment **117***b*.

The labyrinth seal **140** extends circumferentially around the annular space, is externally coupled to the implement **121**, and includes an enlarged-diameter external surface **147** into which a plurality of circumferentially-extending and axially-spaced labyrinth grooves **148***a* are formed, thus defining a plurality of circumferentially-extending and axially-spaced labyrinth teeth **148***b* interposed between the labyrinth grooves **148***a*. The enlarged-diameter external surface **147** extends proximate an internal surface of the external wall **146** of the downhole tool **100**. The amount of clearance between the enlarged-diameter external surface **147** of the labyrinth seal **140** and the internal surface of the external wall **146** of the downhole tool **100** can be tailored to provide different amounts of "slowing" for different applications.

In operation, when the implement **121** (and thus the labyrinth seal **140**) is moved in the direction **123***b*, a portion of the dampening fluid **145** disposed in the internal space **120***b* on the other side **145***a* of the labyrinth seal **140** flows between the labyrinth seal **140** and the internal surface of the external wall **146**, past the labyrinth grooves **148***a* and the labyrinth teeth **148***b*, and into the internal space **120***b* on the one side **145***b* of the labyrinth seal **140**; in one or more embodiments, the labyrinth seal **140** provides resistance to this flow of the dampening fluid **145**, thereby slowing the actuation speed of the implement **121** in the direction **123***b*. Likewise, when the implement **121** (and thus the labyrinth seal **140**) is moved in the direction **123***a*, a portion of the dampening fluid **145** disposed in the internal space **120***b* on one side **145***b* of the labyrinth seal **140** flows between the labyrinth seal **140** and the internal surface of the external wall **146**, past the labyrinth grooves **148***a* and the labyrinth teeth **148***b*, and into the internal space **120***b* on the other side **145***a* of the labyrinth seal **140**; in one or more embodiments, the labyrinth seal **140** provides resistance to this flow of the dampening fluid **145**, thereby slowing the actuation speed of the implement **121** in the direction **123***a*.

In one or more embodiments, the labyrinth seal **140** dampens the actuation speed of the downhole tool **100** in the direction **123***a*, the direction **123***b*, or both, thereby ensuring proper actuation of the downhole tool **100** without damaging the downhole tool **100** or other systems/devices associated with the downhole tool **100**.

Referring to FIG. **4**A, in an embodiment, the dampener **115** is or includes a guide rod assembly **149** including a guide rod **150** and an orifice **155**. The guide rod **150** defines opposing end portions **151***a* and **151***b* and extends within a guide cylinder **152**, which guide cylinder defines opposing end portions **153***a* and **153***b*. A sealing head **154** at the end portion **151***a* of the guide rod **150** sealingly and slidably engages an internal surface of the guide cylinder **152**. The end portion **151***b* of the guide rod **150** is connected to the implement **121** of the actuation assembly **110** so that, when the implement **121** moves in the direction **123***a*, the guide rod **150** also moves in the direction **123***a* and, when the implement **121** moves in the direction **123***b*, the guide rod **150** also moves in the direction **123***b*.

The orifice **155** is formed through an orifice tube **156** connected to the guide cylinder **152** at the end portion **153***a*. The orifice **155** opens, along an internal tapered (e.g., frustoconical) surface **157***a* into an enlarged-diameter internal passage **158***a* of the orifice tube **156** on a side of the orifice tube **156** adjacent the guide cylinder **152**. Likewise, the orifice **155** opens, along an internal tapered (e.g., frustoconical) surface **157***b* into an enlarged-diameter internal passage **158***b* of the orifice tube **156** on a side of the orifice tube **156** opposite the guide cylinder **152**.

A dampening fluid **159** is disposed within the enlarged-diameter internal passage **158***a*, the orifice **155**, and the enlarged-diameter internal passage **158***b*. In operation, when the implement **121** (and thus the guide rod **150**) is moved in the direction **123***b*, a portion of the dampening fluid **159** disposed within the enlarged-diameter internal passage **158***a* on the side of the orifice **155** adjacent the guide cylinder **152** flows along the internal tapered surface **157***a*, through the orifice **155**, and into the enlarged-diameter internal passage **158***b*; in one or more embodiments, the orifice **155** provides resistance to this flow of the dampening fluid **159**, thereby slowing the actuation speed of the implement **121** in the direction **123***b*. Likewise, when the implement **121** (and thus the guide rod **150**) is moved in the direction **123***a*, a portion of the dampening fluid **159** disposed within the enlarged-diameter internal passage **158***b* on the side of the orifice **155** opposite the guide cylinder **152** flows along the internal tapered surface **157***b*, through the orifice **155**, and into the enlarged-diameter internal passage **158***a*; in one or more embodiments, the orifice **155** provides resistance to this flow of the dampening fluid **159**, thereby slowing the actuation speed of the implement **121** in the direction **123***a*.

In one or more embodiments, the guide rod assembly **149** dampens the actuation speed of the downhole tool **100** in the direction **123***a*, the direction **123***b*, or both, thereby ensuring proper actuation of the downhole tool **100** without damaging the downhole tool **100** or other systems/devices associated with the downhole tool **100**.

In one or more embodiments, the dampener **115** is or includes the guide rod assembly **149** and one or more additional guide rod assembl(ies) substantially identical to the guide rod assembly **149**, each connected to the implement **121**, and collectively distributed around a circumference of the internal wall **130** within the annular space.

Referring to FIG. **4**B, in an embodiment, the dampener **115** is or includes a guide rod assembly **160** including a guide rod **161** with an integral pressure relief member **165**. The guide rod **161** defines opposing end portions **162***a* and **162***b* and extends within a guide cylinder **163**. A sealing head (not shown; substantially identical to the sealing head **154** described above in connection with FIG. **4**A) at the end portion **162***a* of the guide rod **161** sealingly and slidably engages an internal surface of the guide cylinder **163**. The end portion **162***b* of the guide rod **161** is connected to the implement **121** of the actuation assembly **110** so that, when the implement **121** moves in the direction **123***a*, the guide rod **161** also moves in the direction **123***a* and, when the implement **121** moves in the direction **123***b*, the guide rod **161** also moves in the direction **123***b*.

The integral pressure relief member **165** extends within an internal cavity **166** of the guide rod **161**, which internal cavity **166** defines opposing end portions **167***a* and **167***b*. The guide rod **161** includes an internal shoulder **168** defined by the internal cavity **166** and facing the end portion **167***b*. The guide rod **161** also includes a reduced-diameter internal surface **169** proximate the end portion **167***a* of the internal cavity **166**. The integral pressure relief member **165** defines opposing end portions **170***a* and **170***b*. An external shoulder **171** is formed in the integral pressure relief member **165** at the end portion **170***b*, facing the end portion **170***a*. The external shoulder **171** of the integral pressure relief member **165** is adapted to engage the internal shoulder **168** of the guide rod **161**. More particularly, a biasing member such as, for example, a spring **172** urges the external shoulder **171** of the integral pressure relief member **165** into engagement with the internal shoulder **168** of the guide rod **161**. A seal **173** is sealingly engaged between the end portion **170***a* of the integral pressure relief member **165** and the reduced-diameter internal surface **169** of the guide rod **161** when the external shoulder **171** of the integral pressure relief member **165** engages the internal shoulder **168** of the guide rod **161**.

The integral pressure relief member **165** is activated based on an increase in back-pressure during actuation of the downhole tool **100** in the direction **123***b*. More particularly, activation of the integral pressure relief member **165** occurs when the back-pressure within the end portion **167***a* of the internal cavity **166** urges the integral pressure relief member **165** in the direction **123***a*, relative to the guide rod **161**, and against the spring **172**. When the back-pressure within the end portion **167***a* of the internal cavity **166** overcomes the biasing force imparted to the integral pressure relief member **165** by the spring **172**, the integral pressure relief member **165** moves in the direction **123***a* and relative to the guide rod **161**, disengaging the sealing engagement of the seal **173** between the end portion **170***a* of the integral pressure relief member **165** and the reduced-diameter internal surface **169** of the guide rod **161**. This disengagement of the seal **173** opens fluid communication between the end portion **167***a* of the internal cavity **166** and the end portion **167***b* of the internal cavity **166**. One or more ports **174** are formed radially through the guide rod **161** from the end portion **167***b* of the internal cavity **166**. As a result, when the seal **173** is disengaged by an increase in back-pressure during actuation of the downhole tool **100** in the direction **123***b*, a dampening fluid **180** bypasses the integral pressure relief member **165**, flowing from the end portion **167***a* of the internal cavity **166**, into the end portion **167***b* of the internal cavity **166**, and through the port(s) **174**; in one or more embodiments, the integral pressure relief member **165** resists this flow of the dampening fluid **180**, thereby slowing the actuation speed of the implement **121** in the direction **123***b*.

In addition, or instead, the guide rod **161** may include a secondary miniature relief valve **185** operable to alleviate pressure buildup when the downhole tool **100** is actuated in the direction **123***a*. The secondary miniature relief valve **185** extends within an internal cavity **186** of the integral pressure relief member **165**, which internal cavity **186** defines opposing end portions **187***a* and **187***b*. The end portion **187***a* of the internal cavity **186** has an enlarged diameter, and the end portion **187***b* of the internal cavity **186** has a reduced diameter. An internal tapered (e.g., frustoconical) surface **188** extends between the end portion **187***a* of the internal cavity **186** (having the enlarged diameter) and the end portion **187***b* of the internal cavity **186** having the reduced diameter, facing the end portion **187***a* of the internal cavity **186** having the enlarged diameter. A pressure relief member **189** is urged into sealing engagement with the internal tapered surface **188** by a biasing member such as, for example, a spring **190**.

The secondary miniature relief valve **185** is activate based on an increase in backpressure during actuation of the downhole tool **100** in the direction **123***a*. More particularly, activation of the secondary miniature relief valve **185** occurs when the back-pressure within the end portion **187***b* of the internal cavity **186** urges the pressure relief member **189** in the direction **123***b*, relative to the integral pressure relief member **165**, and against the spring **190**. When the back-pressure within the end portion **187***b* the internal cavity **186** overcomes the biasing force imparted to the pressure relief member **189** by the spring **190**, the pressure relief member **189** moves in the direction **123***b* and relative to the integral pressure relief member **165**, disengaging the sealing engagement of the pressure relief member **189** from the internal tapered surface **188** of the integral pressure relief member **165**. This disengagement of the pressure relief member **189** opens fluid communication between the end portion **187***b* of the internal cavity **186** and the end portion **187***a* of the internal cavity **186**.

One or more ports **191** are formed radially through the integral pressure relief member **165** from the end portion **187***a* of the internal cavity **186**. As a result, when the pressure relief member **189** is disengaged by an increase in back-pressure during actuation of the downhole tool **100** in the direction **123***a*, the dampening fluid **180** bypasses the pressure relief member **189**, flowing through the port(s) **174**, into the end portion **167***b* of the internal cavity **166**, through the port(s) **191**, into the end portion **187***b* of the internal cavity **186**, past the pressure relief member **189**, into the end portion **187***a* of the internal cavity **186**, and into the end portion **167***a* of the internal cavity **166**; in one or more embodiments, the pressure relief member **189** resists this flow of the dampening fluid **180**, thereby slowing the actuation speed of the implement **121** in the direction **123***a*. More particularly, in such embodiments, the secondary miniature relief valve **185** slows the actuation speed of the downhole tool **100** in the direction **123***a* (e.g., during opening of the downhole tool **100**, thereby preventing a pressure lock), and the integral pressure relief member **165** slows the actuation speed of the downhole tool **100** in the direction **123***b* (e.g., during closing of the downhole tool **100**).

In one or more embodiments, the guide rod assembly **160** dampens the actuation speed of the downhole tool **100** in the direction **123***a*, the direction **123***b*, or both, thereby ensuring proper actuation of the downhole tool **100** without damaging the downhole tool **100** or other systems/devices associated with the downhole tool **100**.

In one or more embodiments, the dampener **115** is or includes the guide rod assembly **160** and one or more additional guide rod assembl(ies) substantially identical to the guide rod assembly **160**, each connected to the implement **121**, and collectively distributed around a circumference of the internal wall **130** within the annular space.

Referring to FIG. **5**A, in an embodiment, the dampener **115** is or includes a sleeve **192** having a slot such as, for example, a helical slot **195** formed therein, and a guide **200** adapted to engage the helical slot **195**. The helical slot **195** defines a pitch angle **205** that determines the actuation speed of the downhole tool **100** in both the direction **123***a* and the direction **123***b*. The sleeve **192** extends within the internal space **120***b* (shown in FIGS. **2**A, **2**B, and **3**) of the downhole tool **100** and defines opposing end portions **206***a* and **206***b*. The end portion **206***b* of the sleeve **192** is connected to the implement **121** (shown in FIGS. **2**A and **2**B) of the actuation assembly **110** so that, when the implement **121** moves in the direction **123***a*, the sleeve **192** also moves in the direction **123***a* and, when the implement **121** moves in the direction **123***b*, the sleeve **192** also moves in the direction **123***b*. The helical slot **195** is formed externally into the sleeve **192**. The guide **200** includes a bearing assembly **210** having a rotating component **211** and a stationary component **212**. The stationary component **212** is connected to or otherwise operably associated with the external wall **146** (shown in FIG. **3**) of the downhole tool **100**. The rotating component **211** is rotatable relative to the stationary component **212**, via a bearing component **213**, and includes a body **214** and a pin **215** extending radially inwardly from the body **214**. The pin **215** extends into, and is adapted to ride along, the helical slot **195** in the sleeve **192**.

In operation, when the implement **121** (and thus the sleeve **192**) is moved in the direction **123***a*, the pin **215** rides along the helical slot **195**, causing the rotating component **211** of the bearing assembly **210** to rotate relative to the stationary component **212**, via the bearing component **213**, and slowing the actuation speed of the downhole tool **100** in the direction **123***a*. The pitch angle **205** can be tailored to provide different amounts of "slowing" for different applications. Similarly, when the implement **121** (and thus the sleeve **192**) is moved in the direction **123***b*, the pin **215** rides along the helical slot **195** in the opposite direction, causing the rotating component **211** of the bearing assembly **210** to rotate relative to the stationary component **212**, via the bearing component **213**, and slowing the actuation speed of the downhole tool **100** in the direction **123***b*.

In one or more embodiments, the sleeve **192** and the guide **200**, in combination, dampen the actuation speed of the downhole tool **100** in the direction **123***a*, the direction **123***b*, or both, thereby ensuring proper actuation of the downhole tool **100** without damaging the downhole tool **100** or other systems/devices associated with the downhole tool **100**.

Although described as being formed externally into the sleeve **192**, the helical slot **195** may instead be formed internally into the sleeve **192**; in such embodiments, rather than being connected to or otherwise operably associated with the external wall **146** of the downhole tool **100**, the stationary component **212** of the bearing assembly **210** is connected to or otherwise operably associated with the internal wall **130** of the downhole tool **100**, so that the pin **215** of the rotating component **211** extends radially inwardly into the helical slot **195** formed internally into the sleeve **192**.

Referring to FIG. **5**B, in an embodiment, the dampener **115** is or includes a sleeve **220** having a slot such as, for example, a J-slot **225** formed therein, and a guide **230** adapted to engage the J-slot **225**. The J-slot **225** includes a straight portion **231***a*, a transitional portion **231***b*, and a helical portion **231***c*. The helical portion **231***c* of the J-slot **225** defines a pitch angle **235**. The sleeve **220** extends within the internal space **120***b* (shown in FIGS. **2**A, **2**B, and **3**) of the downhole tool **100** and defines opposing end portions **236***a* and **236***b*. The end portion **236***b* of the sleeve **220** is connected to the implement **121** (shown in FIGS. **2**A and **2**B) of the actuation assembly **110** so that, when the implement **121** moves in the direction **123***a*, the sleeve **220** also moves in the direction **123***a* and, when the implement **121** moves in the direction **123***b*, the sleeve **220** also moves in the direction **123***b*. The J-slot **225** is formed externally into the sleeve **220**. The guide **230** is substantially identical to the guide **200** and therefore, will not be described in further detail; more particularly, the guide **230** includes feature(s)/component(s) substantially identical to corresponding feature(s)/component(s) of the guide **200**, which substantially identical feature(s)/component(s) are given the same reference numerals. The pin **215** of the guide **230** extends into, and is adapted to ride along, the J-slot **225** in the sleeve **220**.

In operation, when the implement **121** (and thus the sleeve **220**) is moved in the direction **123***a*, the pin **215** rides along the straight portion **231***a* of the J-slot **225**, so that the rotating component **211** of the bearing assembly **210** does not rotate relative to the stationary component **212**, via the bearing component **213**, and the actuation speed of the downhole tool **100** in the direction **123***a* is not slowed. The transitional portion **231***b* of the J-slot **225** connects the straight portion **231***a* to the helical portion **231***c*, defining a pitch angle **237**. As the pin **215** nears the end portion **236***a* of the sleeve **220**, the pin **215** exits the straight portion **231***a* of the J-slot **225** and passes through the transitional portion **231***b*, into the helical portion **231***c*. The pitch angle **237** of the transitional portion **231***b* slows the actuation speed of the downhole tool in the direction **123***a*, at least when the pin **215** extends within the transitional portion **231***b*, causing the rotating component **211** of the bearing assembly **210** to rotate relative to the stationary component **212**, via the bearing component **213**. The pitch angle **237** of the transitional portion **231***b* can be tailored for different applications to provide different amounts of "slowing" while the downhole tool **100** is actuated in the direction **123***a* and the pin **215** extends within the transitional portion **231***b* of the J-slot **225**. Once the pin **215** enters the helical portion **231***c* of the J-slot **225**, the implement **121** (and thus the sleeve **220**) may be moved in the direction **123***b*, causing the pin **215** to ride along the helical portion **231***c* of the J-slot **225** in the opposite direction. As the pin **215** rides along the helical portion **231***c* of the J-slot **225** in the opposite direction, the rotating component **211** of the bearing assembly **210** rotates relative to the stationary component **212**, via the bearing component **213**, slowing the actuation speed of the downhole tool **100** in the direction **123***b*, at least until the pin **215** re-enters the straight portion **231***a* of the J-slot **225** at an intersection **240** between the helical portion **231***c* and the straight portion **231***a*, at which point the actuation speed of the downhole tool **100** in the direction **123***b* is no longer slowed. The pitch angle **235** of the helical portion **231***c* of the J-slot **225** can be tailored for different applications to provide different amounts of "slowing" while downhole tool is actuated in the direction **123***b* and the pin **215** extends within the helical portion **231***c* of the J-slot **225**.

In one or more embodiments, the sleeve **220** and the guide **230**, in combination, dampen the actuation speed of the downhole tool **100** in the direction **123***a*, the direction **123***b*, or both, thereby ensuring proper actuation of the downhole tool **100** without damaging the downhole tool **100** or other systems/devices associated with the downhole tool **100**.

Although described as being formed externally into the sleeve **220**, the J-slot **225** may instead be formed internally into the sleeve **220**; in such embodiments, rather than being connected to or otherwise operably associated with the external wall **146** of the downhole tool **100**, the stationary component **212** of the bearing assembly **210** is connected to or otherwise operably associated with the internal wall **130** of the downhole tool **100**, so that the pin **215** of the rotating component **211** extends radially inwardly into the J-slot **225** formed internally into the sleeve **220**.

A downhole tool has been disclosed. The downhole tool generally includes: a first implement; an actuator adapted to actuate the first implement in a first direction; a biasing device adapted to actuate the first implement in a second direction, opposite the first direction; a dampener adapted to slow an actuation speed of the first implement in the first direction, the second direction, or both; and a flow control device ("FCD") including a flow member and a second implement to which the first implement is connected; wherein actuating the first implement in the first direction also actuates the second implement in the first direction to place the flow member in a first configuration; and wherein actuating the first implement in the second direction also actuates the second implement in the second direction to place the flow member in a second configuration. In one or more embodiments, the first configuration in which the flow member is placed when the second implement is actuated in the first direction is or includes an open configuration in which the flow member permits fluid flow through the downhole tool; and the second configuration in which the flow member is placed when the second implement is actuated in the second direction is or includes a closed configuration in which the flow member prevents, or at least reduces, fluid flow through the downhole tool. In one or more embodiments, the FCD extends within a first internal space of the downhole tool; the first implement, the actuator, the biasing device, and the dampener extend within a second internal space of the downhole tool; and the second internal space is external to the first internal space. In one or more embodiments, the second internal space is separated from the first internal space by an internal wall of the downhole tool; the first internal space is or includes a central flow passageway of the downhole tool; and the second internal space is or includes an annular space of the downhole tool located between the internal wall and an external wall of the downhole tool. In one or more embodiments, the dampener is or includes a labyrinth seal. In one or more embodiments, the dampener is or includes a guide rod assembly, the guide rod assembly including a guide rod and: an orifice; or an integral pressure relief member. In one or more embodiments, the guide rod assembly includes: the guide rod; the integral pressure relief member; and a secondary miniature relief valve. In one or more embodiments, the dampener is or includes a sleeve having a slot and formed therein, and a guide adapted to engage the slot. In one or more embodiments, at least a portion of the slot is helical. In one or more embodiments, the slot is or includes a J-slot.

A method has also been disclosed. The method generally includes: actuating, using an actuator of a downhole tool, a first implement in a first direction; actuating, using a biasing device of the downhole tool, the first implement in a second direction, opposite the first direction; and slowing, using a dampener of the downhole tool, an actuation speed of the first implement in the first direction, the second direction, or both. In one or more embodiments, actuating the first implement in the first direction also actuates a second implement of a flow control device ("FCD") of the downhole tool, to which the first implement is connected, in the first direction, placing a flow member of the FCD, to which the second implement is connected, in a first configuration; and actuating the first implement in the second direction also actuates the second implement of the FCD in the second direction, placing the flow member in a second configuration. In one or more embodiments, the first configuration in which the flow member is placed when the second implement is actuated in the first direction is or includes an open configuration in which the flow member permits fluid flow through the downhole tool; and the second configuration in which the flow member is placed when the second implement is actuated in the second direction is or includes a closed configuration in which the flow member prevents, or at least reduces, fluid flow through the downhole tool.

An apparatus has also been disclosed. The apparatus generally includes: an implement; an actuator adapted to actuate the implement in a first direction; a biasing device adapted to actuate the implement in a second direction, opposite the first direction; and a dampener adapted to slow an actuation speed of the implement in the first direction, the second direction, or both. In one or more embodiments, the dampener is or includes a labyrinth seal. In one or more embodiments, the dampener is or includes a guide rod assembly, the guide rod assembly including a guide rod and: an orifice; or an integral pressure relief member. In one or more embodiments, the guide rod assembly includes: the guide rod; the integral pressure relief member; and a secondary miniature relief valve. In one or more embodiments, the dampener is or includes a sleeve having a slot and formed therein, and a guide adapted to engage the slot. In one or more embodiments, at least a portion of the slot is helical. In one or more embodiments, the slot is or includes a J-slot.

It is understood that variations may be made in the foregoing without departing from the scope of the present disclosure.

In several embodiments, the elements and teachings of the various embodiments may be combined in whole or in part in some (or all) of the embodiments. In addition, one or more of the elements and teachings of the various embodiments may be omitted, at least in part, and/or combined, at least in part, with one or more of the other elements and teachings of the various embodiments.

Any spatial references, such as, for example, "upper," "lower," "above," "below," "between," "bottom," "vertical," "horizontal," "angular," "upwards," "downwards," "side-to-side," "left-to-right," "right-to-left," "top-to-bottom," "bottom-to-top," "top," "bottom," "bottom-up," "top-down," etc., are for the purpose of illustration only and do not limit the specific orientation or location of the structure described above.

In several embodiments, while different steps, processes, and procedures are described as appearing as distinct acts, one or more of the steps, one or more of the processes, and/or one or more of the procedures may also be performed in different orders, simultaneously and/or sequentially. In several embodiments, the steps, processes, and/or procedures may be merged into one or more steps, processes and/or procedures.

In several embodiments, one or more of the operational steps in each embodiment may be omitted. Moreover, in some instances, some features of the present disclosure may be employed without a corresponding use of the other features. Moreover, one or more of the above-described embodiments and/or variations may be combined in whole or in part with any one or more of the other above-described embodiments and/or variations.

Although several embodiments have been described in detail above, the embodiments described are illustrative only and are not limiting, and those skilled in the art will readily appreciate that many other modifications, changes and/or substitutions are possible in the embodiments without materially departing from the novel teachings and advantages of the present disclosure. Accordingly, all such modifications, changes, and/or substitutions are intended to be included within the scope of this disclosure as defined in the following claims. In the claims, any means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures. Moreover, it is the express intention of the applicant not to invoke 35 U.S.C. § 112(f) for any limitations of any of the claims herein, except for those in which the claim expressly uses the word "means" together with an associated function.

What is claimed is:

1. A downhole tool, comprising:

a first implement;

an actuator adapted to actuate the first implement in a first direction;

a biasing device adapted to actuate the first implement in a second direction, opposite the first direction;

a dampener adapted to slow an actuation speed of the first implement in the first direction, the second direction, or both wherein:

the dampener is or includes a guide rod assembly including a guide rod, and an orifice or an integral pressure relief member; or

the dampener is or includes a sleeve having a slot formed therein, and a guide adapted to engage the slot; and

a flow control device ("FCD") including a flow sleeve and a second implement to which the first implement is connected;

wherein actuating the first implement in the first direction also actuates the second implement in the first direction to place the flow sleeve in a first configuration; and

wherein actuating the first implement in the second direction also actuates the second implement in the second direction to place the flow sleeve in a second configuration.

2. The downhole tool of claim 1,
wherein the first configuration in which the flow sleeve is placed when the second implement is actuated in the first direction is or includes an open configuration in which the flow sleeve permits fluid flow through the downhole tool; and
wherein the second configuration in which the flow sleeve is placed when the second implement is actuated in the second direction is or includes a closed configuration in which the flow sleeve prevents, or at least reduces, fluid flow through the downhole tool.

3. The downhole tool of claim 1,
wherein the FCD extends within a first internal space of the downhole tool;
wherein the first implement, the actuator, the biasing device, and the dampener extend within a second internal space of the downhole tool; and
wherein the second internal space is external to the first internal space.

4. The downhole tool of claim 3,
wherein the second internal space is separated from the first internal space by an internal wall of the downhole tool;
wherein the first internal space is or includes a central flow passageway of the downhole tool; and
wherein the second internal space is or includes an annular space of the downhole tool located between the internal wall and an external wall of the downhole tool.

5. The downhole tool of claim 1,
wherein the dampener is or includes a labyrinth seal.

6. The downhole tool of claim 1,
wherein the guide rod assembly comprises:
the guide rod;
the integral pressure relief member; and
a secondary miniature relief valve.

7. The downhole tool of claim 1,
wherein at least a portion of the slot is helical.

8. The downhole tool of claim 1,
wherein the second implement is integrally formed with the first implement.

9. A method, comprising:
actuating, using an actuator of a downhole tool, a first implement in a first direction,
wherein actuating the first implement in the first direction also actuates a second implement of a flow control device ("FCD") of the downhole tool, to which the first implement is connected, in the first direction, placing a flow sleeve of the FCD, to which the second implement is connected, in a first configuration;
actuating, using a biasing device of the downhole tool, the first implement in a second direction, opposite the first direction, wherein actuating the first implement in the second direction also actuates the second implement of the FCD in the second direction, placing the flow sleeve in a second configuration; and
slowing, using a dampener of the downhole tool, an actuation speed of the first implement in the first direction, the second direction, or both wherein:
the dampener is or includes a guide rod assembly including a guide rod, and an orifice or an integral pressure relief member; or
the dampener is or includes a sleeve having a slot formed therein, and a guide adapted to engage the slot.

10. The method of claim 9,
wherein the first configuration in which the flow sleeve is placed when the second implement is actuated in the first direction is or includes an open configuration in which the flow sleeve permits fluid flow through the downhole tool; and
wherein the second configuration in which the flow sleeve is placed when the second implement is actuated in the second direction is or includes a closed configuration in which the flow sleeve prevents, or at least reduces, fluid flow through the downhole tool.

11. An apparatus, comprising:
a first implement;
an actuator adapted to actuate the first implement in a first direction;
a biasing device adapted to actuate the first implement in a second direction, opposite the first direction;
a dampener adapted to slow an actuation speed of the first implement in the first direction, the second direction, or both wherein:
the dampener is or includes a guide rod assembly including a guide rod, and an orifice or an integral pressure relief member; or
the dampener is or includes a sleeve having a slot formed therein, and a guide adapted to engage the slot; and
a flow control device ("FCD") including a flow sleeve and a second implement to which the first implement is connected, the flow sleeve and the second implement configured to move in unison with the first implement.

12. The apparatus of claim 11,
wherein the dampener is or includes a labyrinth seal.

13. The apparatus of claim 11,
wherein the guide rod assembly comprises:
the guide rod;
the integral pressure relief member; and
a secondary miniature relief valve.

14. The apparatus of claim 11,
wherein at least a portion of the slot is helical.

15. The apparatus of claim 14,
wherein the slot is or includes a J-slot.

* * * * *